



Royal Netherlands
Meteorological Institute
*Ministry of Infrastructure and the
Environment*

TROPOMI on the ESA Sentinel-5 Precursor

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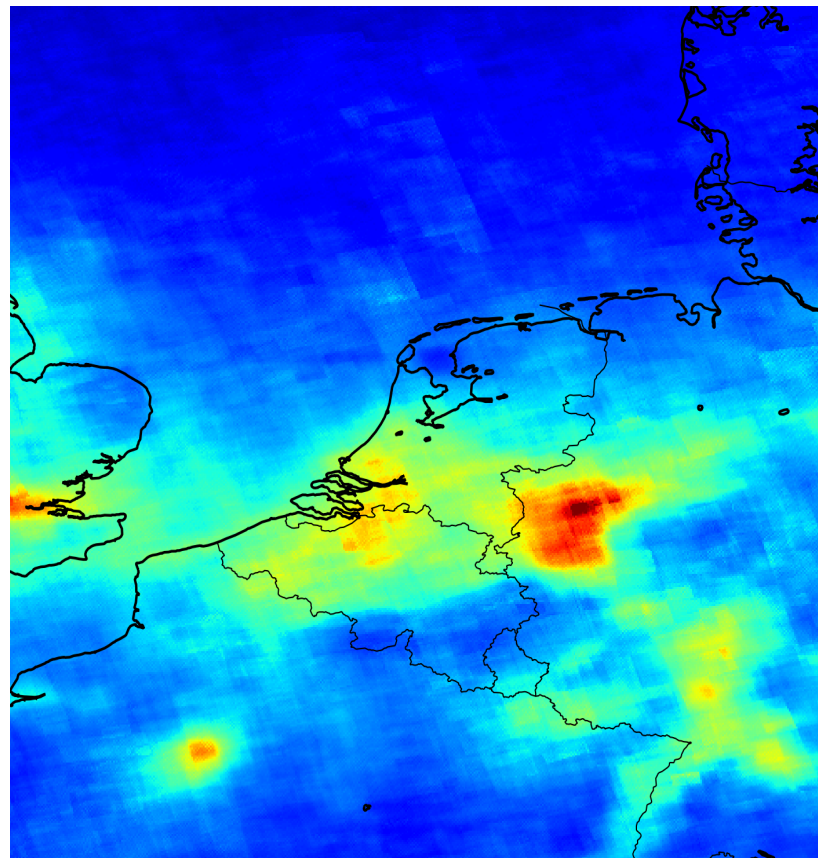
sentinel-5 precursor

GMES ATMOSPHERE MISSION IN POLAR ORBIT

- The ESA Sentinel-5 Precursor (S-5P) is a pre-operational mission focussing on global observations of the atmospheric composition for air quality and climate.
- The TROPospheric Monitoring Instrument (**TROPOMI**) is the payload of the S-5P mission and is jointly developed by The Netherlands and ESA.
- The planned launch date for S-5P is 2014 with a 7 year design lifetime.

TROPOMI

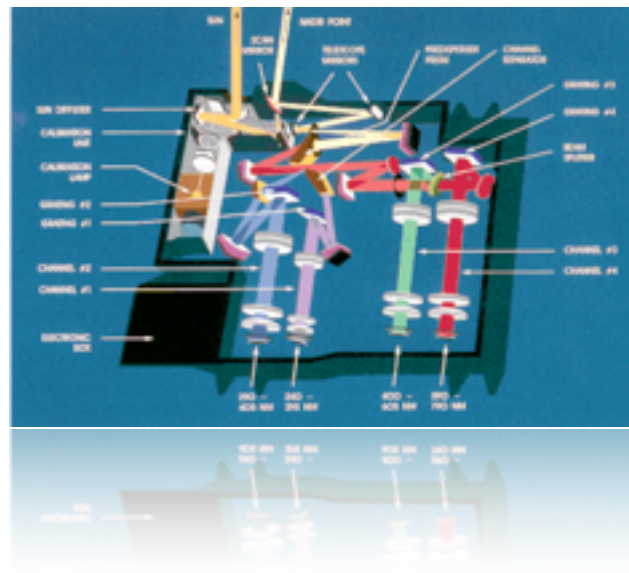
- ▶ UV-VIS-NIR-SWIR nadir view grating spectrometer.
- ▶ Spectral range: 270-500, 675-775, 2305-2385 nm
- ▶ Spectral Resolution: 0.25-1.1 nm
- ▶ Spatial Resolution: 7x7km²
- ▶ Global daily coverage at 13:30 local solar time.



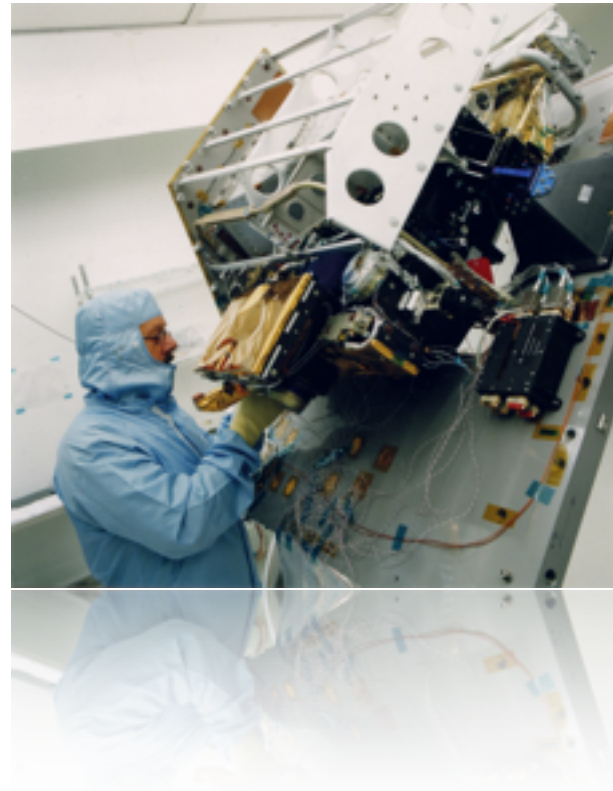
CONTRIBUTION TO GMES

- ▶ Total column
O₃, NO₂, CO, SO₂, CH₄,
CH₂O, H₂O, BrO
- ▶ Tropospheric column
O₃, NO₂
- ▶ O₃ profile
- ▶ Aerosol absorbing index,
type, optical depth

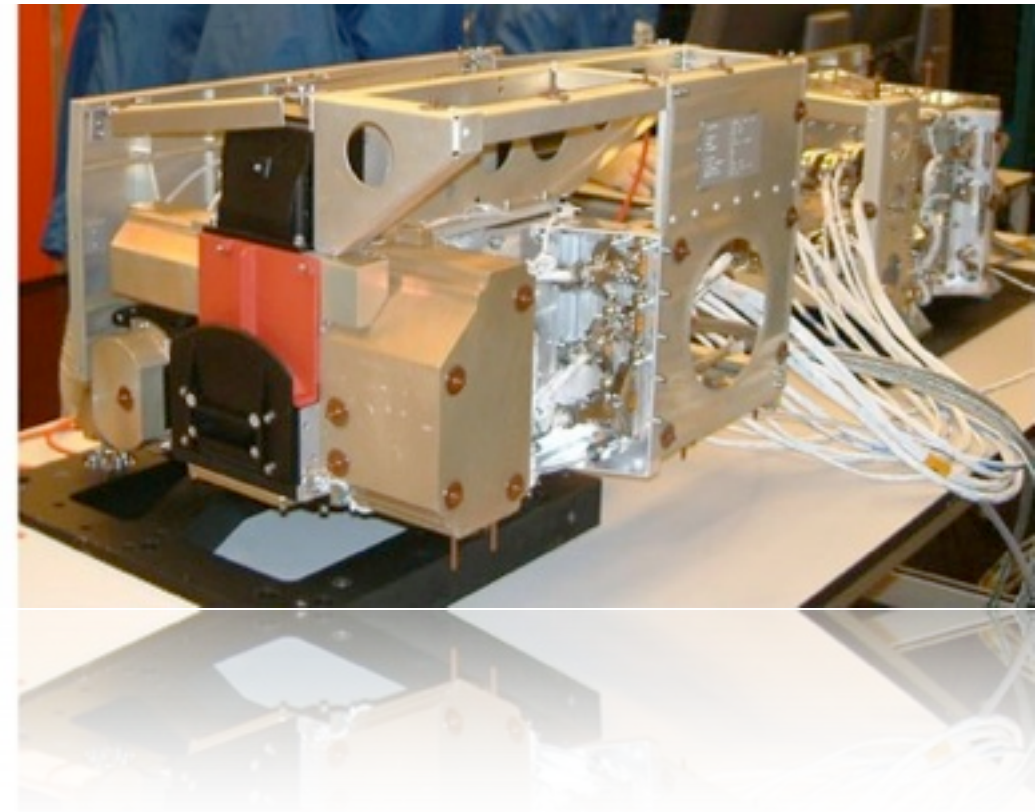
GOME ERS-2, 1995



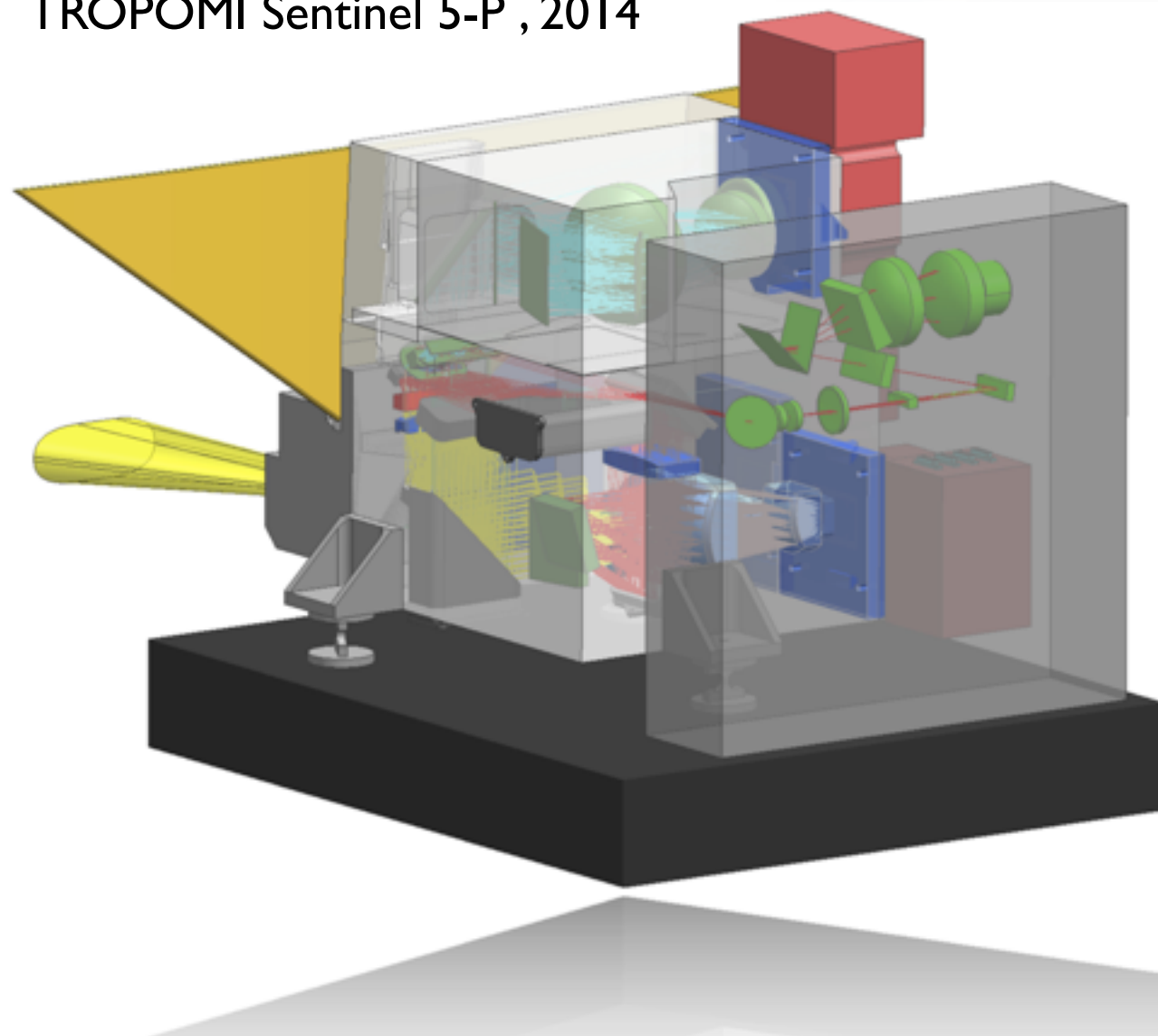
SCIAMACHY Envisat, 2002



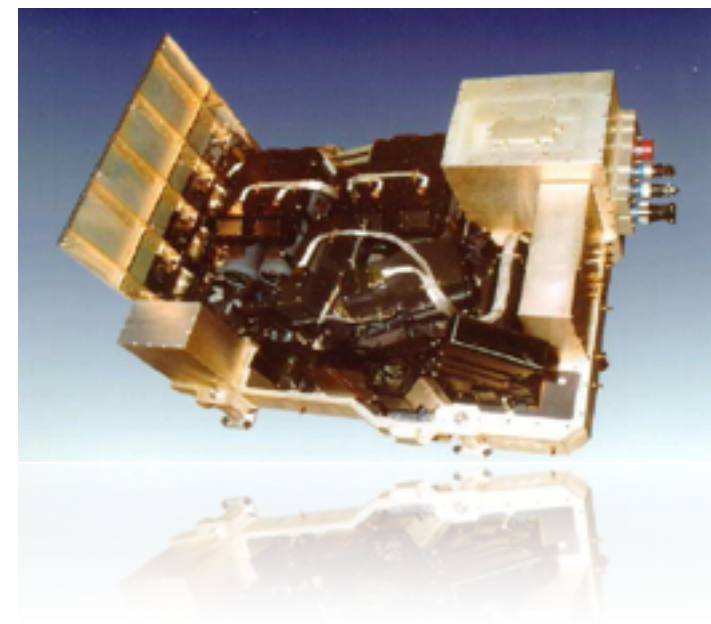
OMI Aura, 2004



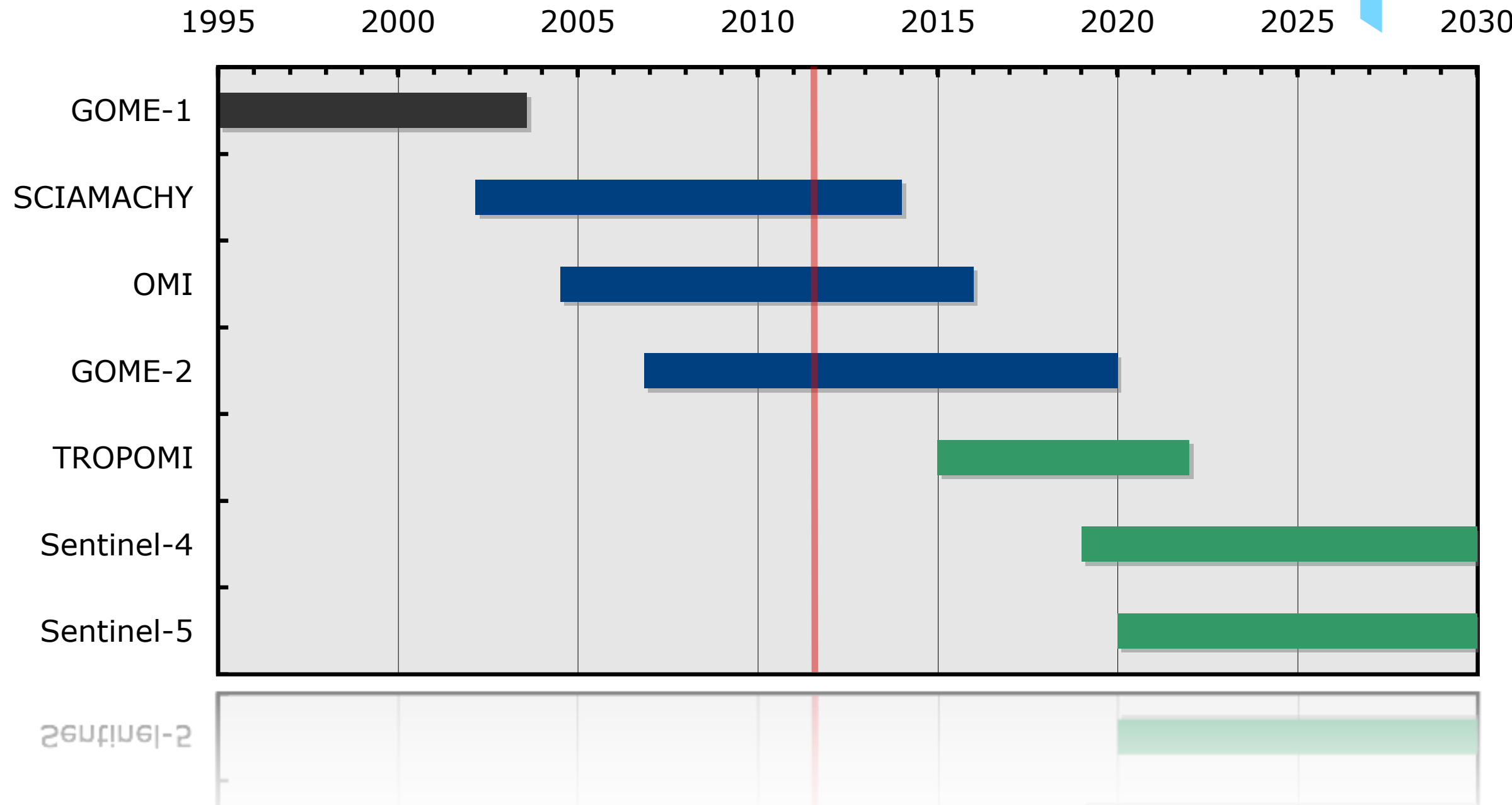
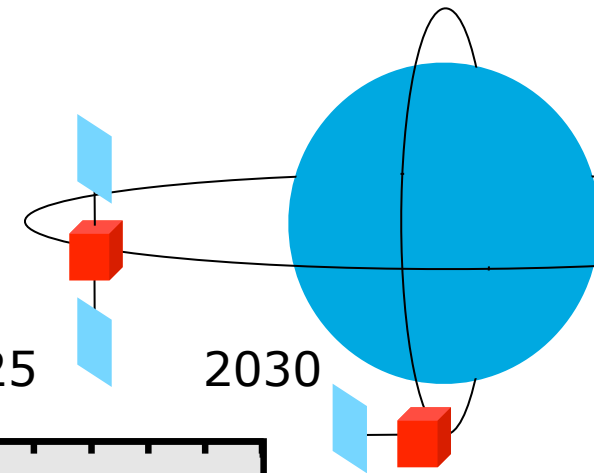
TROPOMI Sentinel 5-P , 2014



GOME-2 Metop , 2006



OMI-TROPOMI-Sentinels



Sentinels 4, 5, and 5-P are part of GMES

Sentinels 4 and 5 will have strong connection with EUMETSAT

- Services Component – led by EC
 - Produces information services in response to European policy priorities in environment and security
 - Relies on data from in-situ and space component
- In-situ component – led by EEA
 - Observations mostly within national responsibility, with coordination at European level
- Space Component – led by ESA
 - Sentinels - EO missions developed specifically for GMES
 - Contributing Missions - EO missions built for purposes other than GMES but offering part of their capacity to GMES

TROPOMI Science Objectives

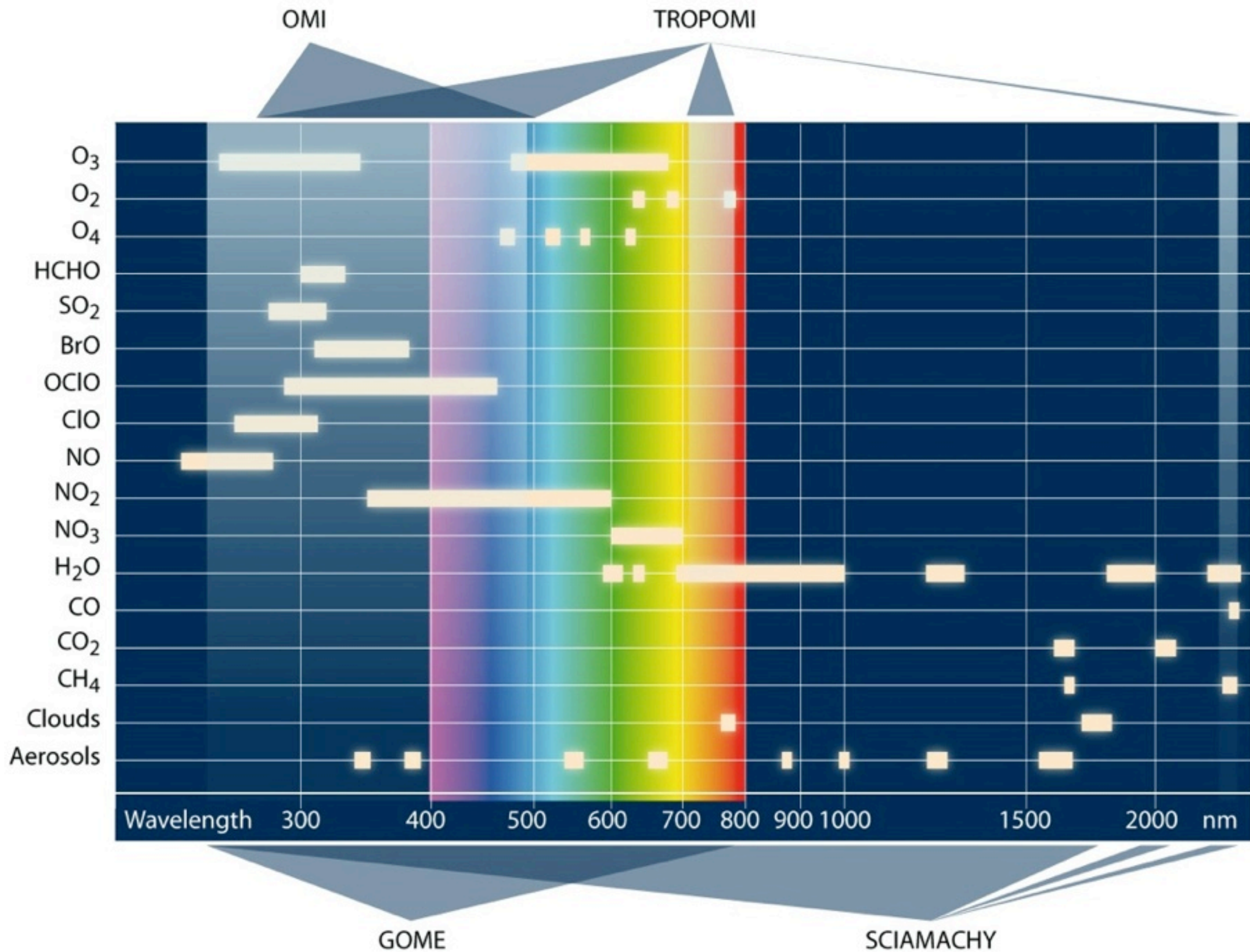
- To better **constrain** the strength, evolution, and spatiotemporal variability of **the sources of trace gases and aerosols** impacting air quality and climate.
- To **improve upon the attribution of climate forcing** by a better understanding of the processes controlling the lifetime and distribution of methane, tropospheric ozone, and aerosols.
- To better estimate **long-term trends** in the troposphere related to air quality and climate from the regional to the global scale.
- To **develop and improve air quality model processes and data assimilation** in support of operational services including air quality forecasting and protocol monitoring.

TROPOMI Data Products

Product	Accuracy :: Precision
ozone total column profile trop. column	3% :: 1% 10% :: 5% 25% :: 10%
NO₂ total column trop. column	1 · 10 ¹⁵ mol/cm ² 10% :: 1 · 10 ¹⁵ mol/cm ²
CO total column	15% :: 10%
CH₄ total column	2% :: 1%
SO₂ volcanic plume top. column	2 DU :: 1 DU 1 DU :: 0.5 DU
Aerosol AAI plume height aerosol optical thickness single scattering albedo	n/a :: 0.25 1 km :: 0.5 km 0.1 (20%) :: 0.05 (10%) 0.05 :: 0.01
Cloud radiance fraction pressure	0.05 :: 0.02 50 hPa :: 20 hPa

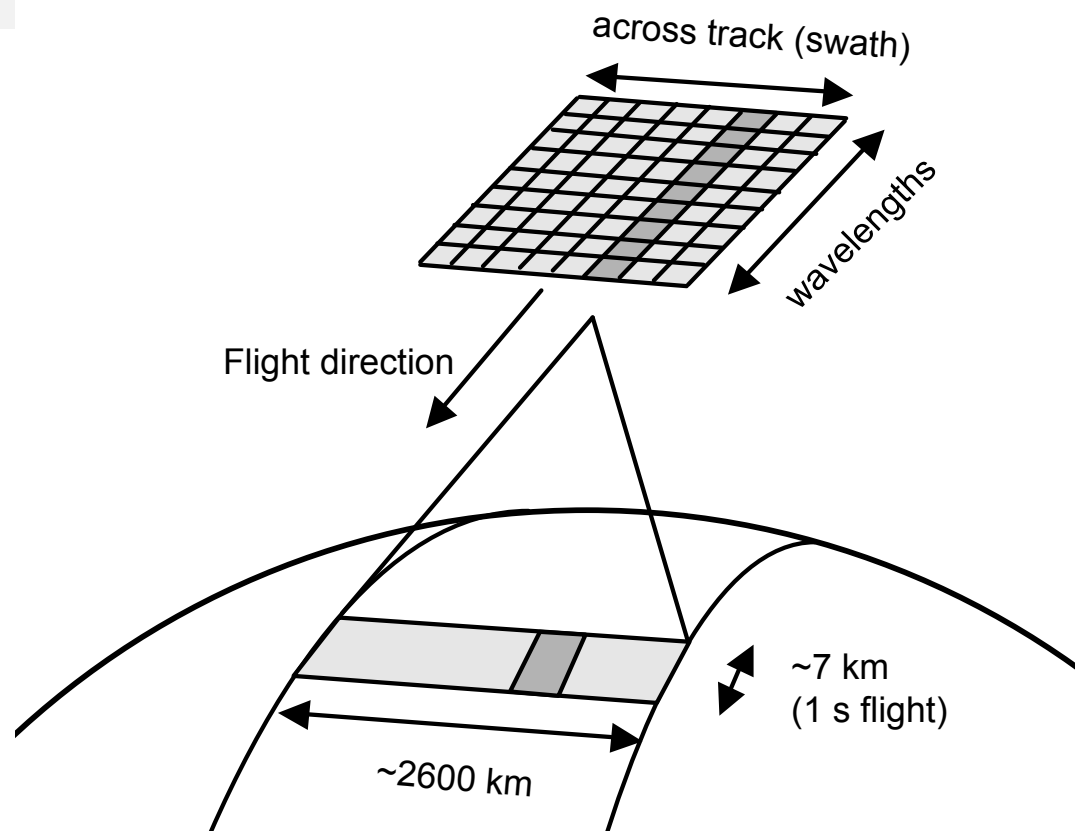
Product	Accuracy :: Precision
CH₂O total column	TBD
CHO-CHO total column	TBD
BrO total column	TBD
HDO total column	TBD
H₂O total column	20% :: 10%
OCIO total column	TBD
UV surface flux	10% :: 5%
Surface Reflectance monthly climatology	3% :: 1%

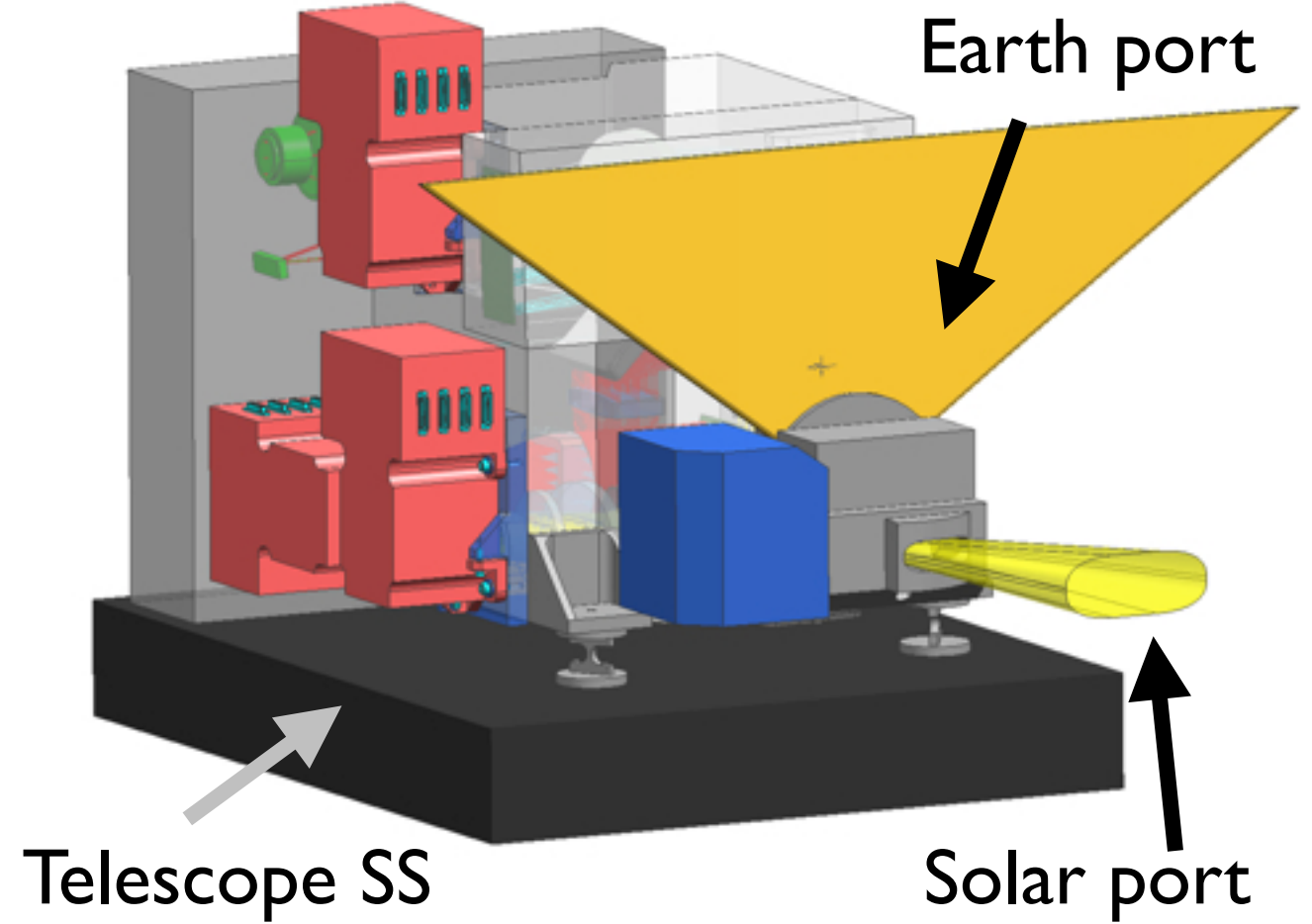
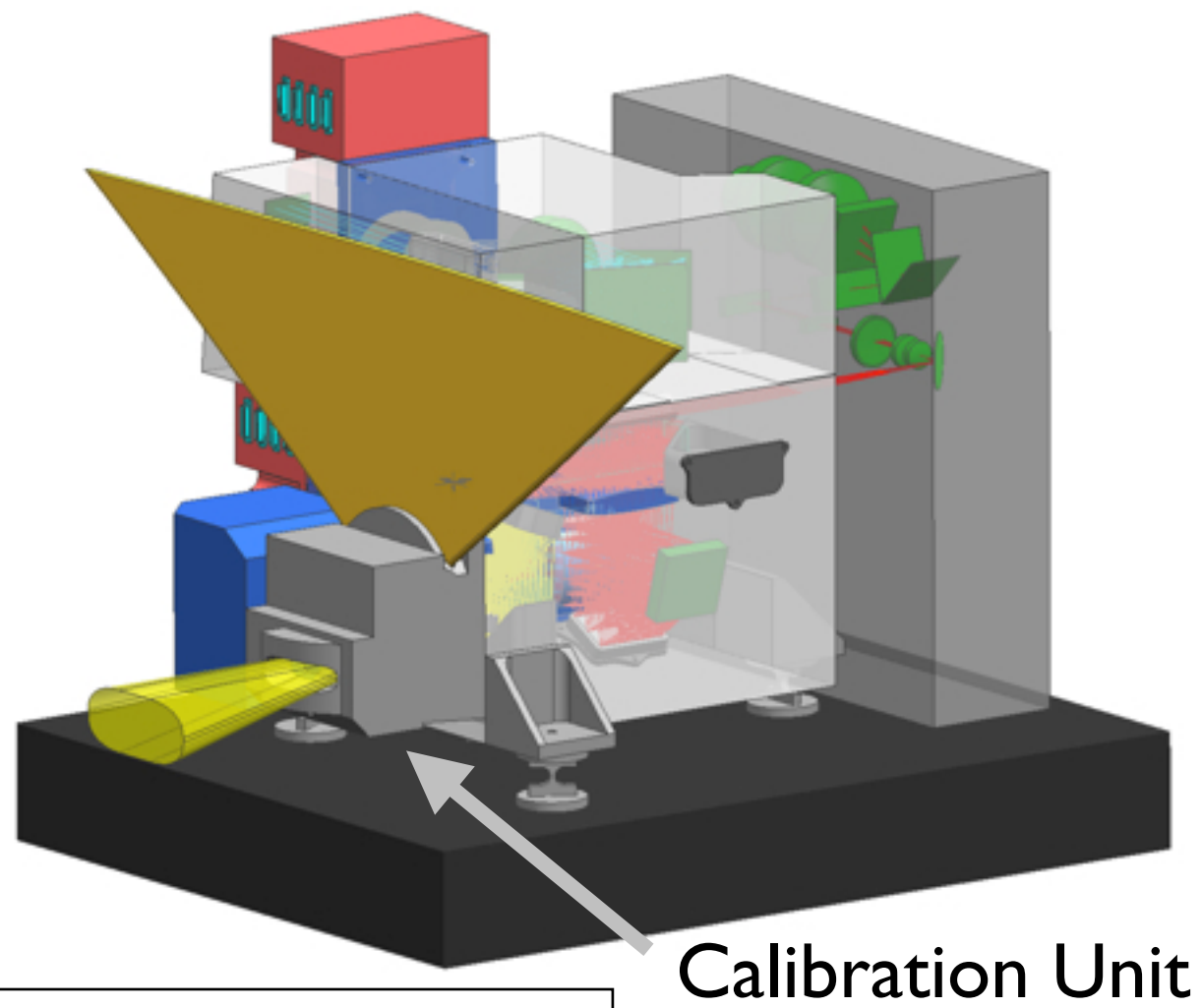
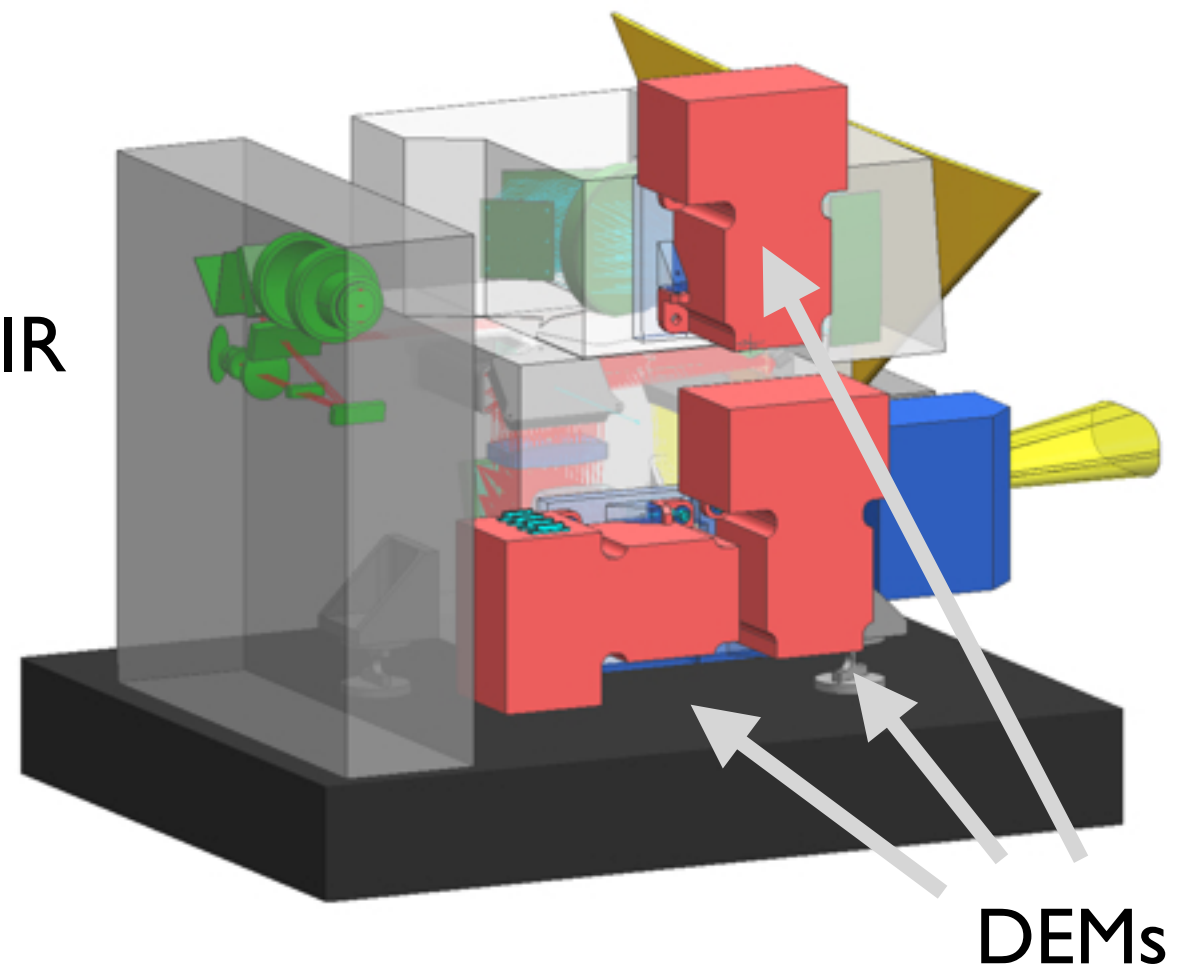
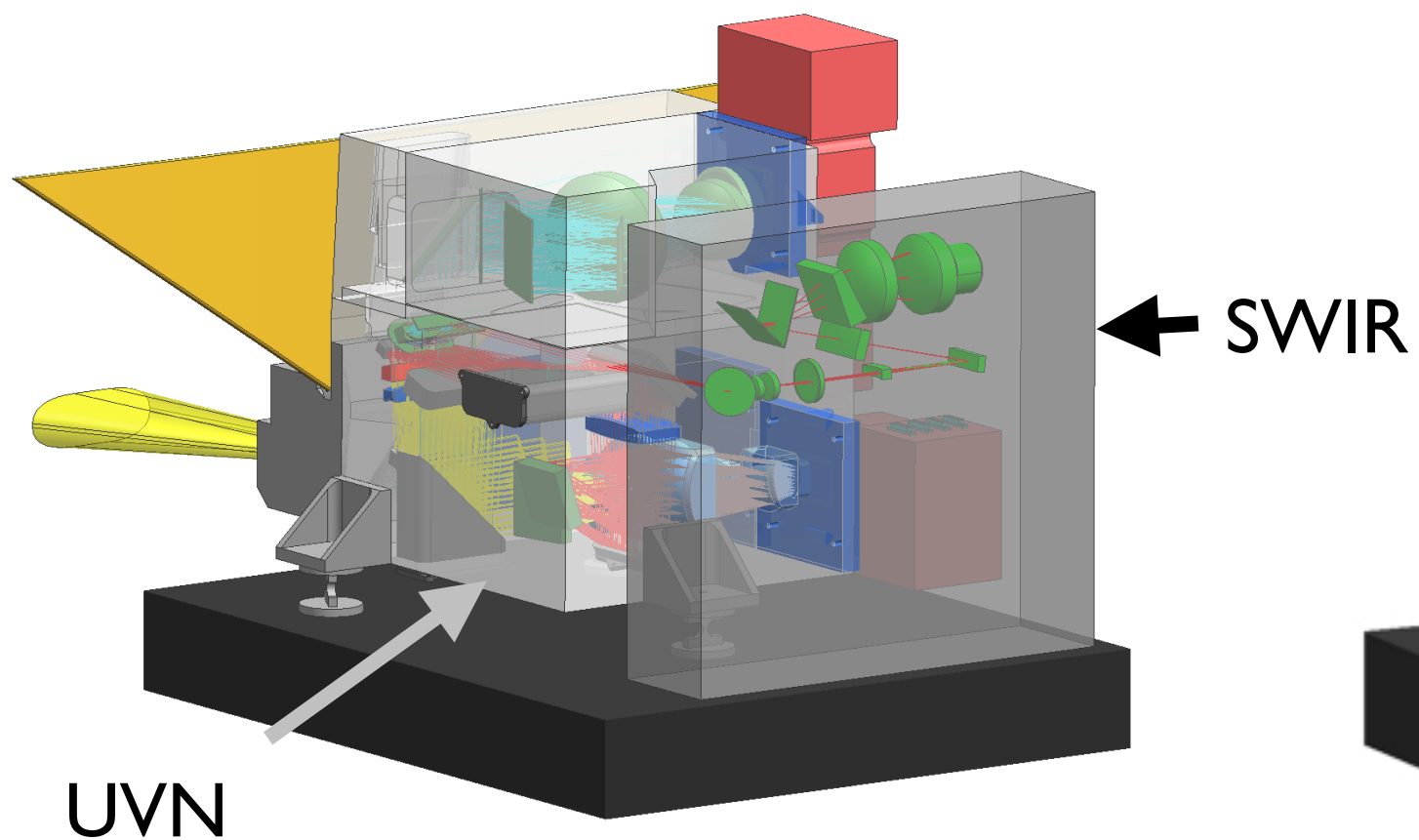
The data products will be developed by KNMI, SRON and a consortium of European institutes.



TROPOMI Spectral Bands

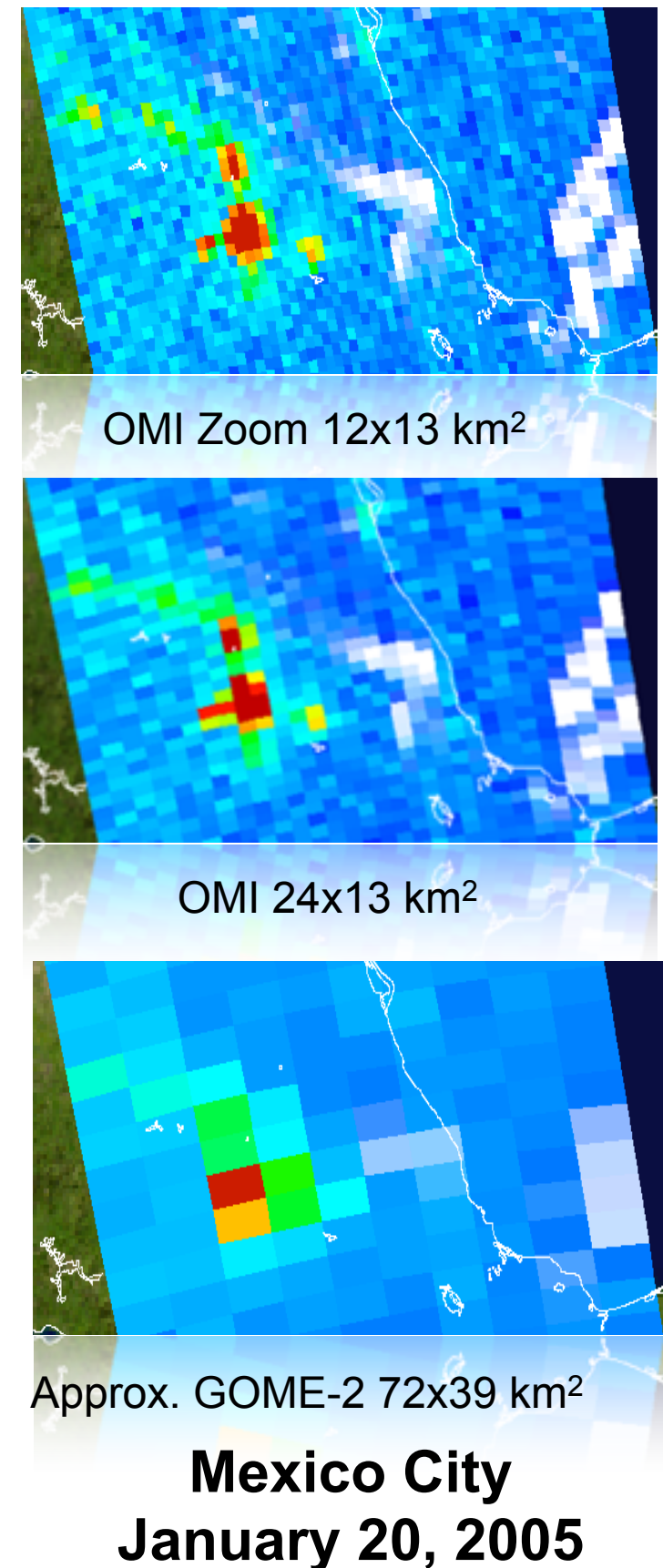
Spectrometer	UV		UVIS		NIR		SWIR
Band ID	1	2	3	4	5	6	7
Spectral range [nm]	270-300	300-320	310-405	405-495	675-725	725-775	2305-2385
Spectral resolution [nm]	0.5	0.5	0.55	0.55	0.5	0.5	0.25
Spectral sampling [nm]	0.06	0.06	0.2	0.2	0.1	0.1	<0.1
Spatial sampling [km ²]	21 x 28	7 x 7	7 x 7	7 x 7	7 x 7	7 x 1.8	7x7
Detector binning factor	16	4	4	4	4	1	1
Minimum	100 ⁽¹⁾	100-	1000-	1500 ⁽¹⁾	500	100-500	100 -120 ⁽²⁾
Signal-to-noise		1000 ⁽¹⁾	1500 ⁽¹⁾				





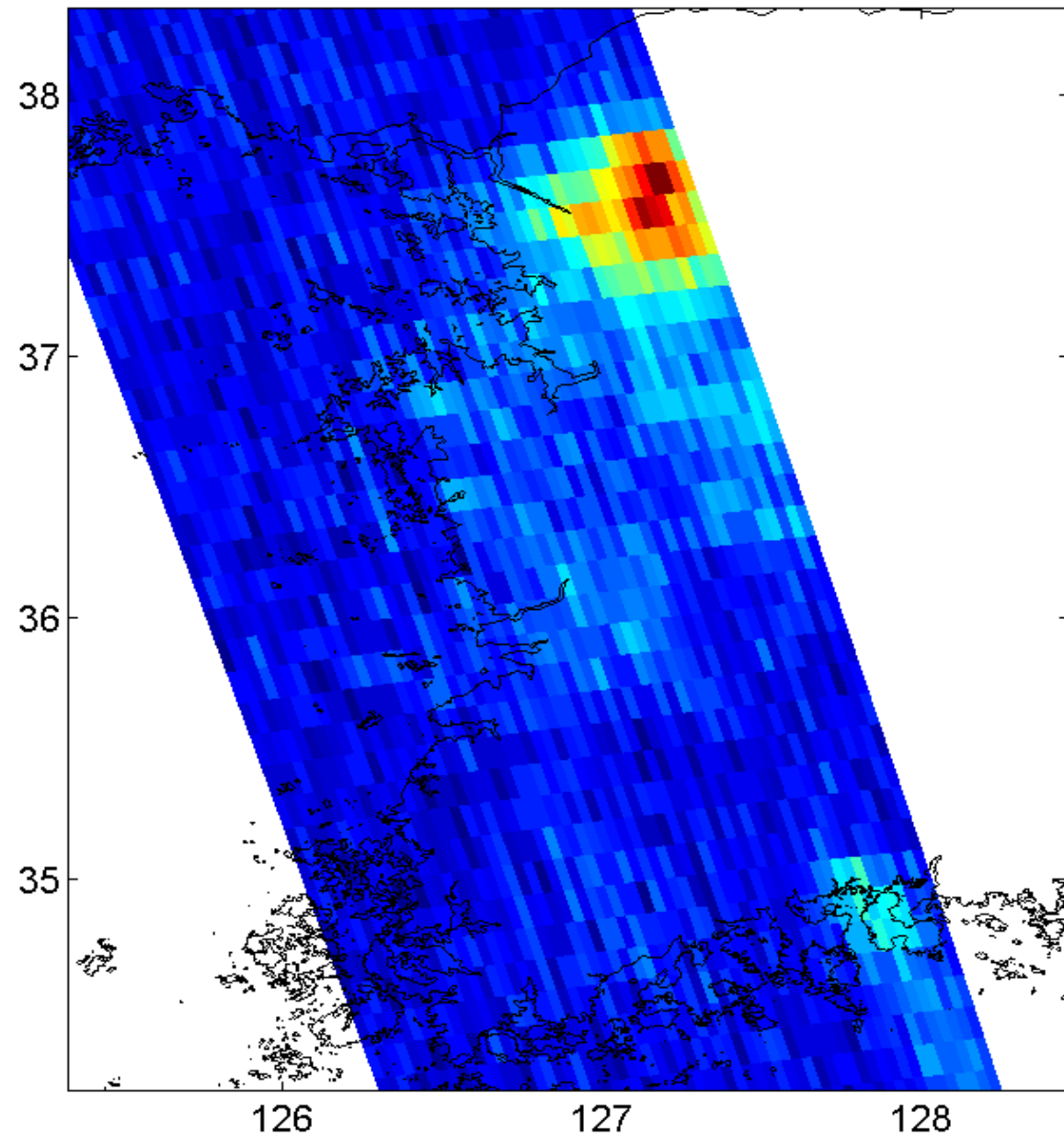
From OMI to TROPOMI

- 6x higher spatial resolution
 $7 \times 7 \text{ km}^2$ vs. $13 \times 24 \text{ km}^2$
- 1-5x higher signal-to-noise
- better cloud information
oxygen A band added
- CO and CH₄ observations
SWIR band added



OMI Super Zoom ~13x3 km² Sampling

South Korea, November 21, 2004



OMI Zoom ~13x12 km² Sampling

12 September 2006

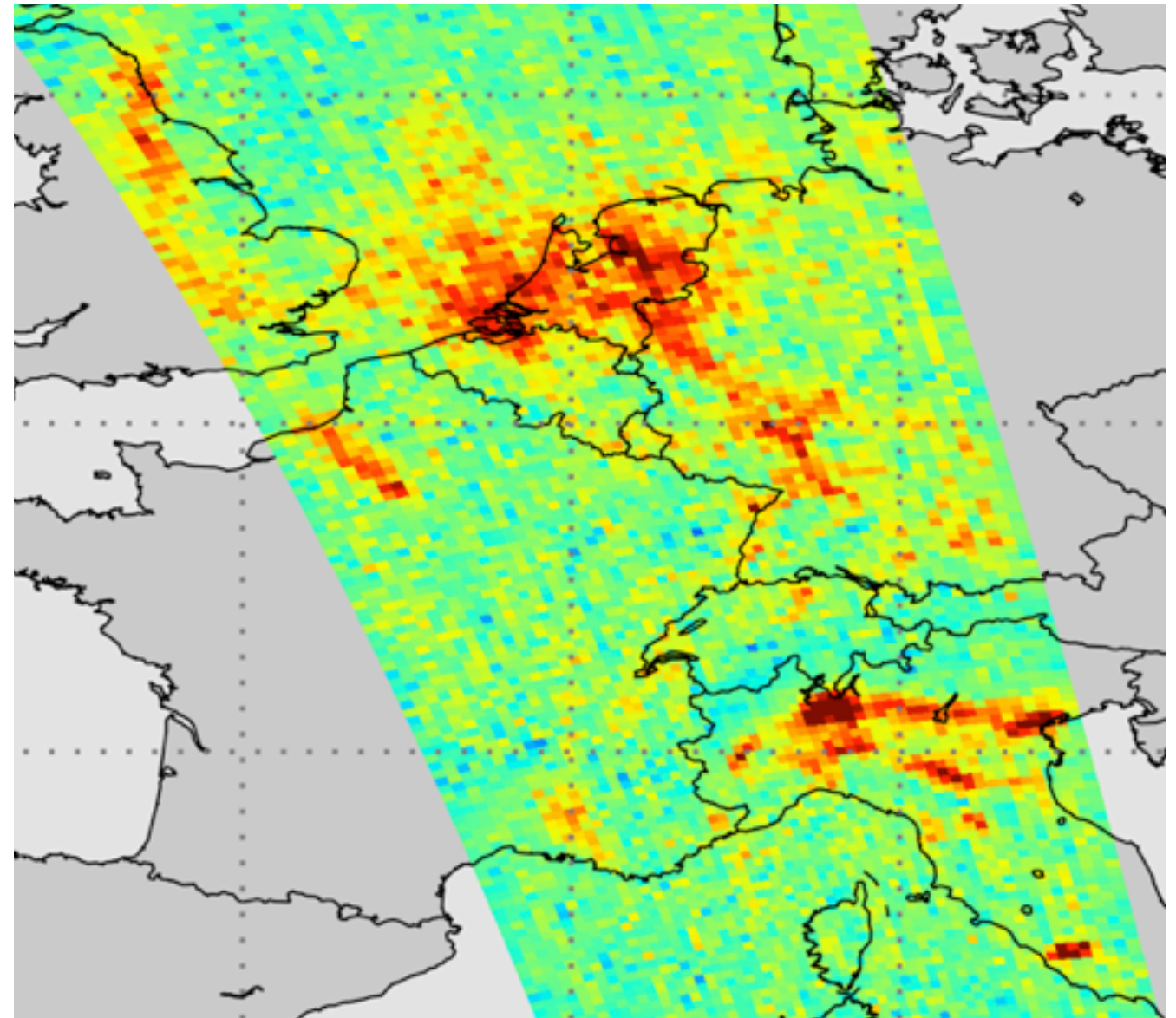
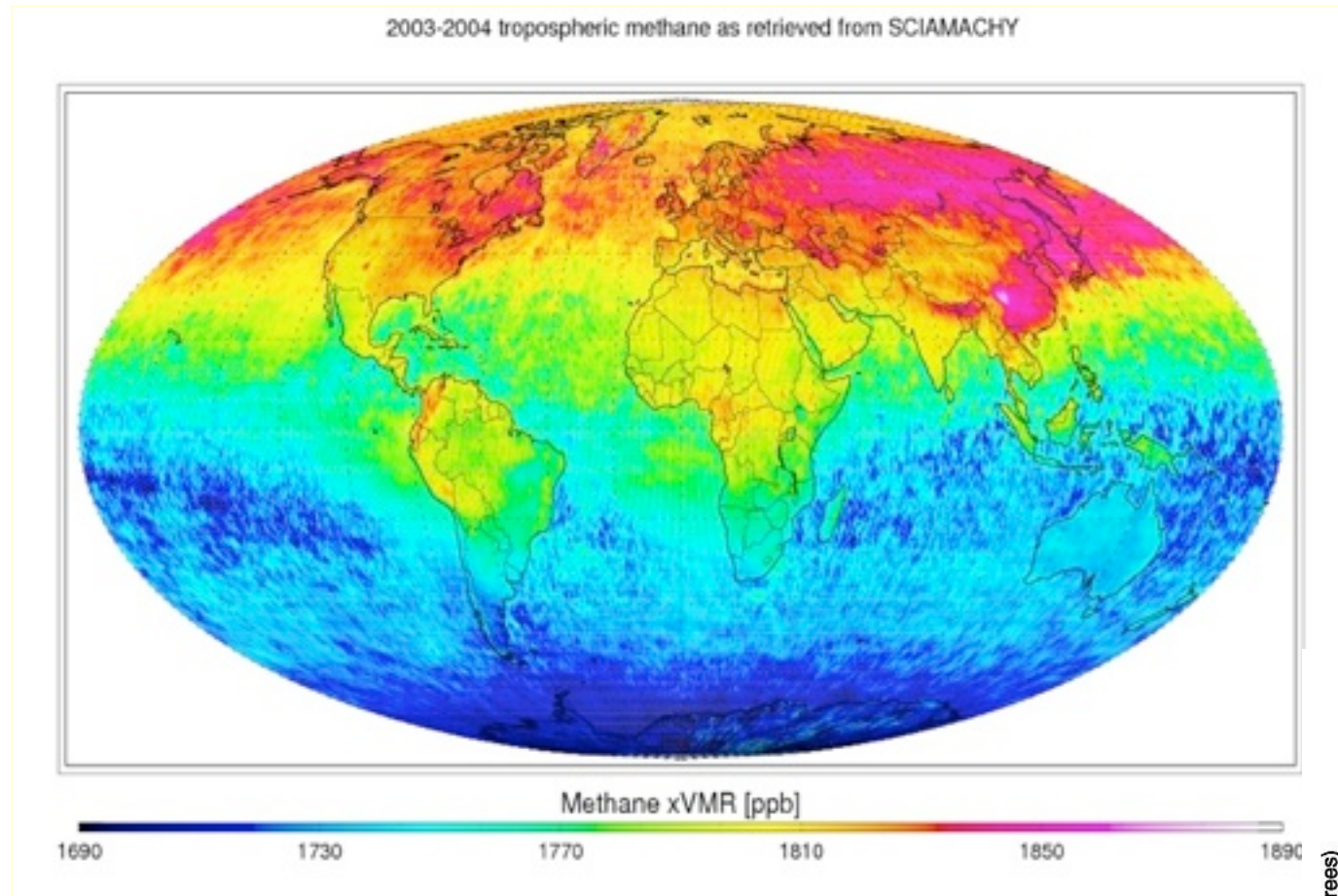


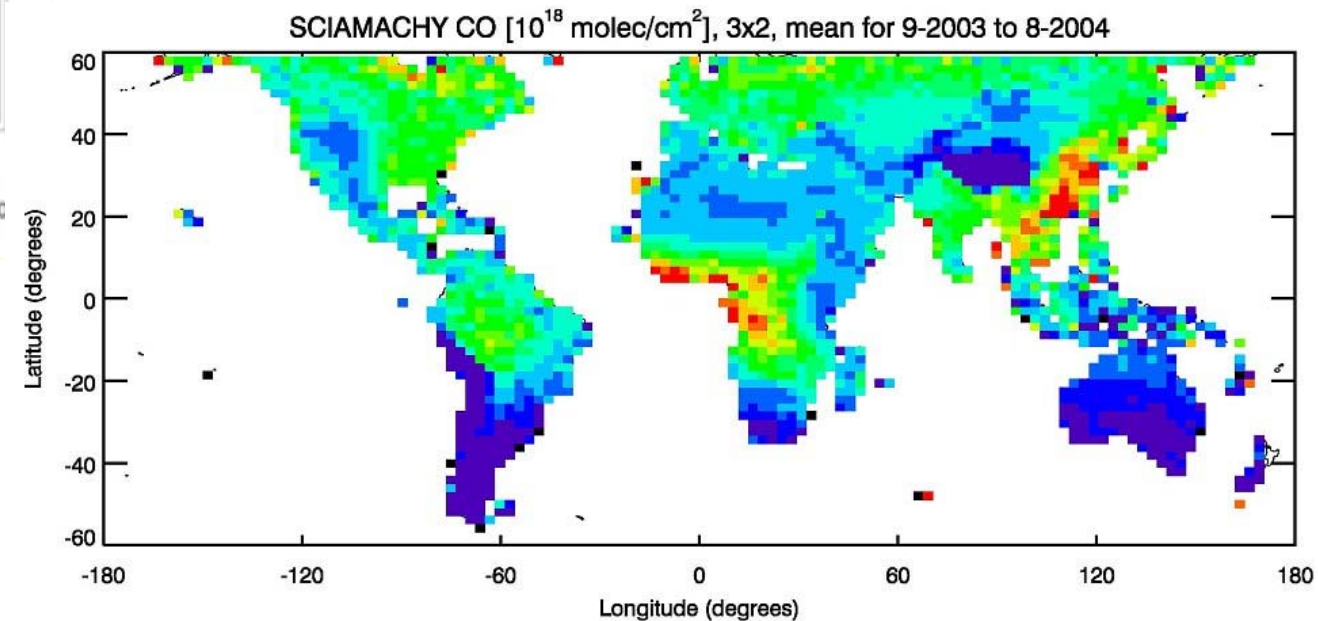
Image courtesy of Ron Cohen

From OMI to TROPOMI

Methane



Carbon Monoxide



Annual mean SCIAMACHY CO (10^{18} molec/cm²)

TROPOMI Data Use

Analysis based on multiple species

Need for consistency in retrieval methods.

Data assimilation

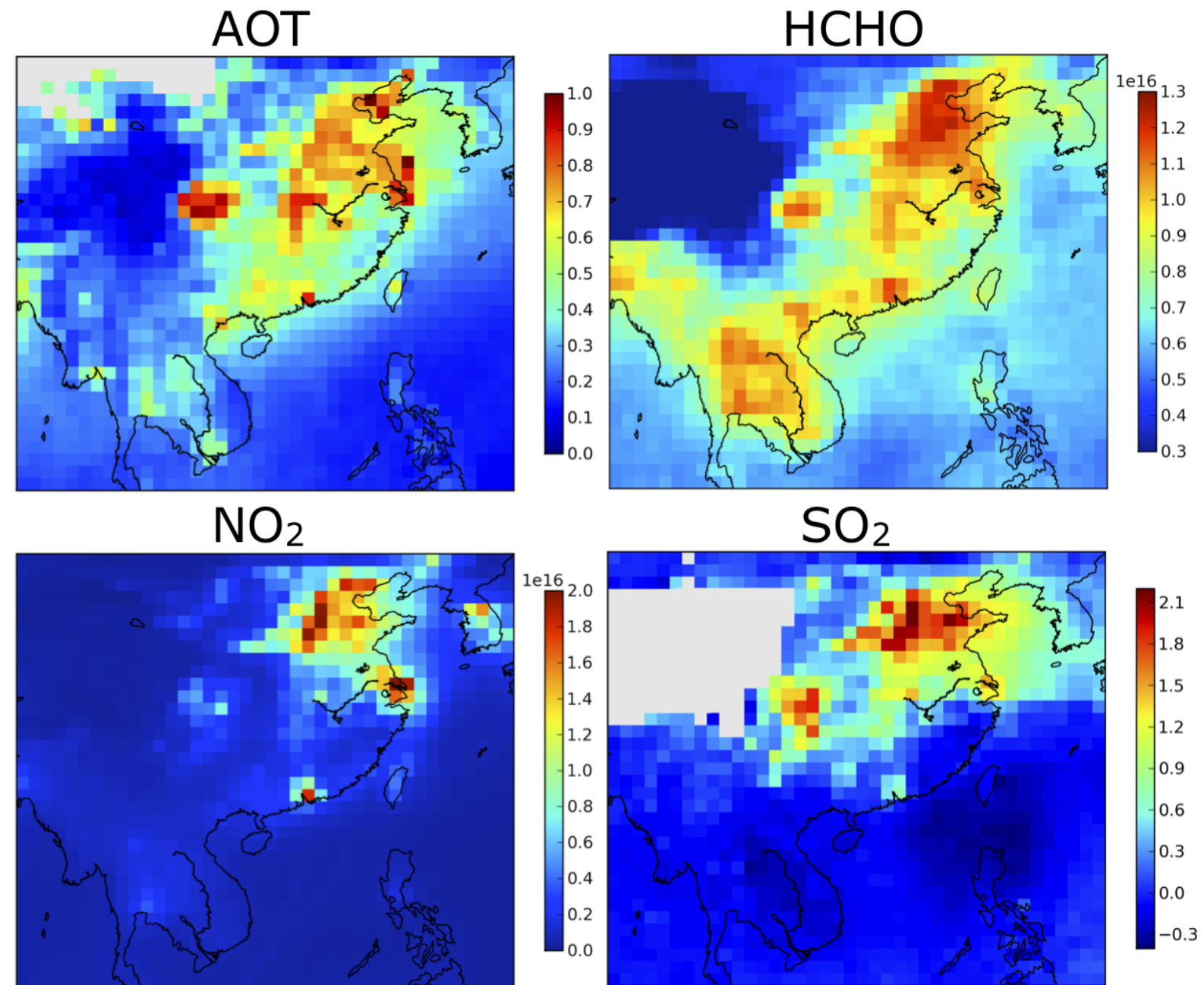
Sophisticated error analysis are needed.

Focus on the troposphere

Sensitivity varies with altitude, aerosols and clouds.

Operational data usage

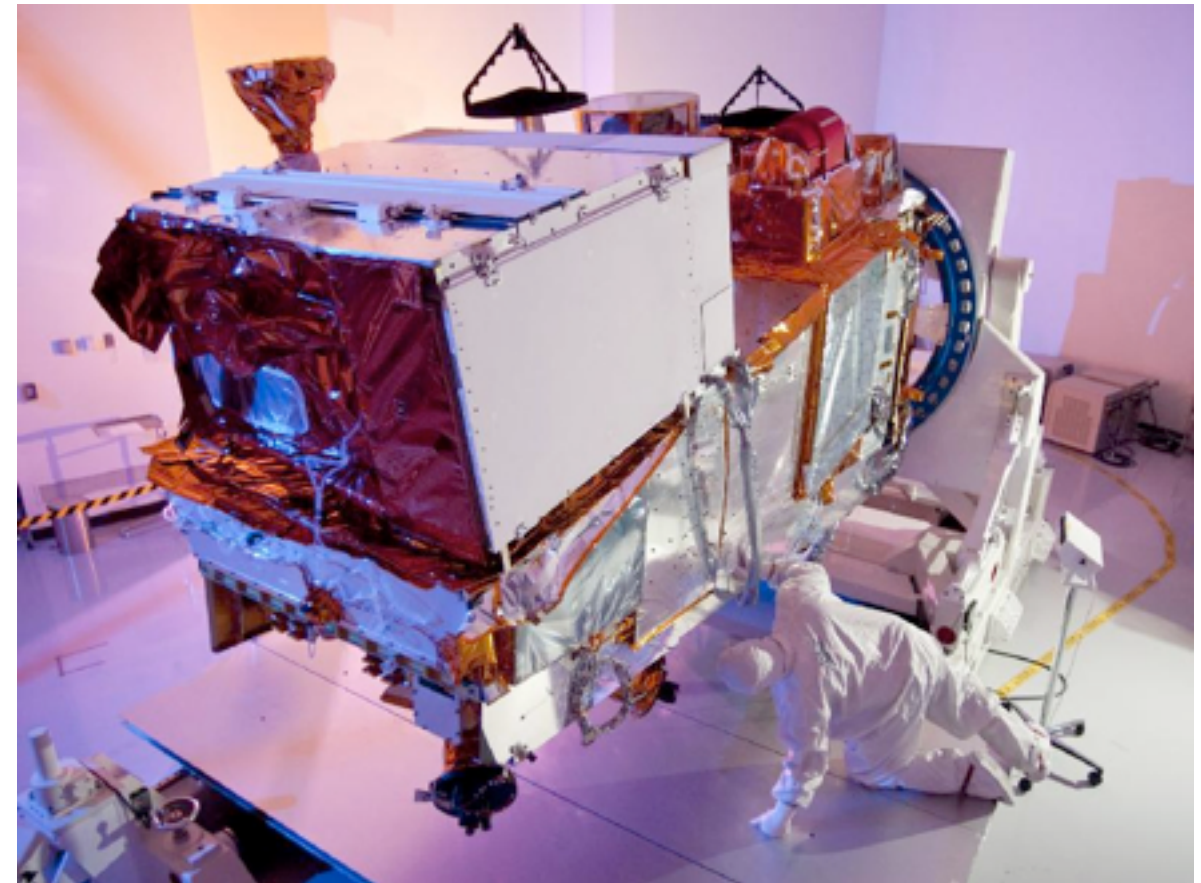
near-real-time data



Veefkind, J. P., et. al.: Atmos. Chem. Phys. Discuss., 10, 18919-18951

NPP/JPSS - S-5P Formation Flying

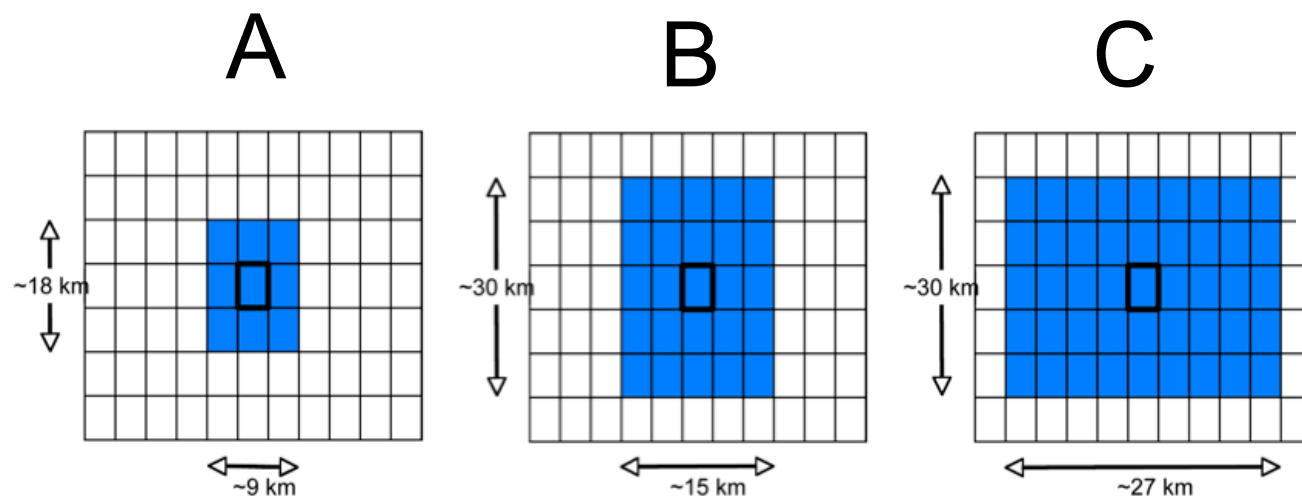
- S-5P is planned to observe within 5 min. of NPP/JPSS.
- Primary goal is to use VIIRS cloud mask for S-5P methane observations.
- Other opportunities:
 - TROPOMI-VIIRS cloud and aerosol combined products.
 - TROPOMI-OMPS-CRIS ozone profiles.
 - TROPOMI-OMPS inter-calibration.



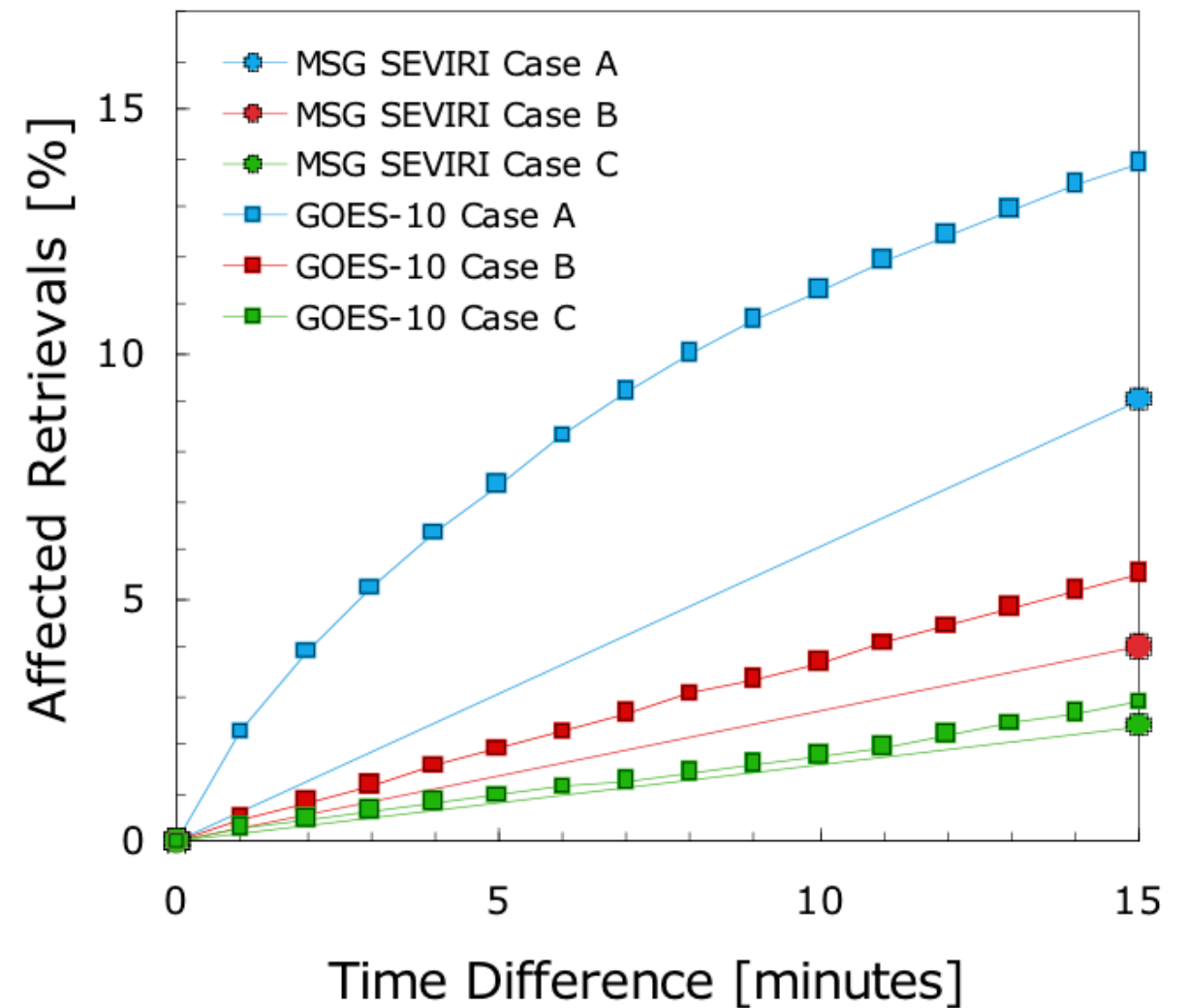
Temporal Co-Reg for TROPOMI/VIIRS

To use VIIRS data for cloud-clearing TROPOMI data the time difference should be less than 1-7 min, depending on cloud-cleared area.

(Genkova et al., submitted to AMTD)



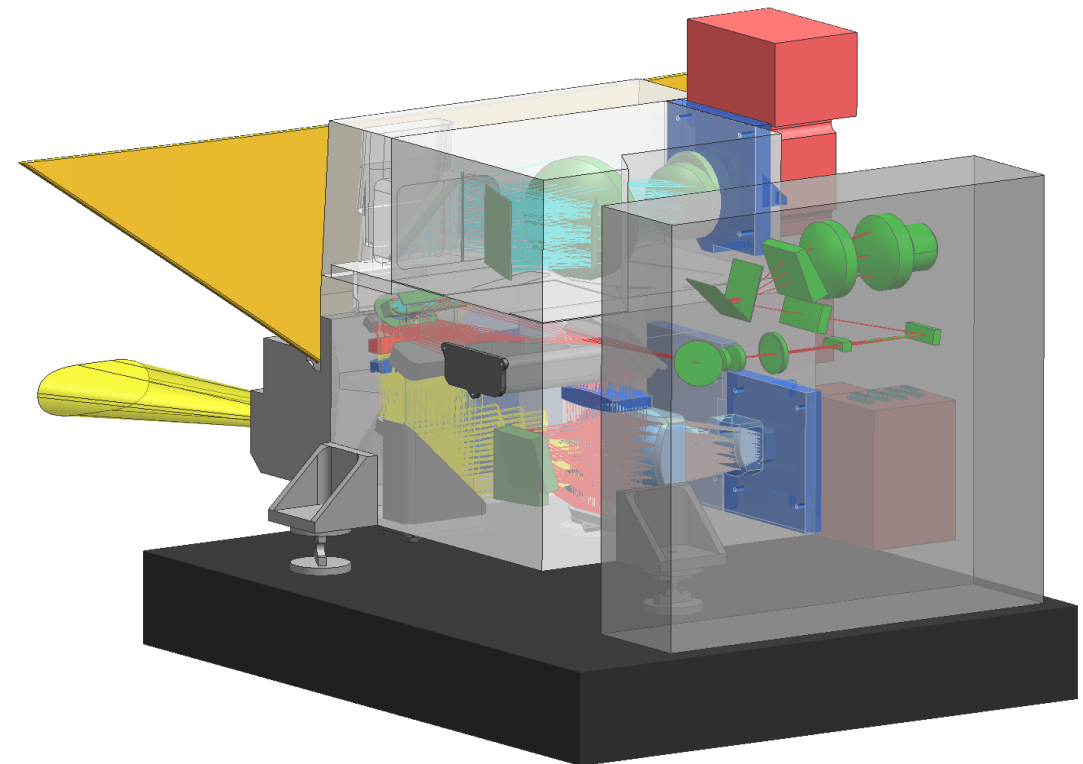
Cases studied: A) cloud cleared region 18x9 km², B) 30x15 km², C) 30x27 km². Center pixel coincides with the target S-5 pixel.



Data sets: MSG SEVIRI cloud mask with 15 min interval for 2006 over Europe, GOES-10 1 minute interval data for 23 August 2006 over the South U.S.A.

Summary

- TROPOMI is a joint development of The Netherlands and ESA; KNMI is PI institute.
- Major improvements compared to OMI are spatial resolution, spectral coverage and signal-to-noise.
- For the TROPOMI data products improved error characterization is anticipated.
- TROPOMI S5-P is the first in a series of ESA/GMES operational UVNS instruments.
- Formation flying with NPP/JPSS is essential for methane product.



OMI Lessons Learned

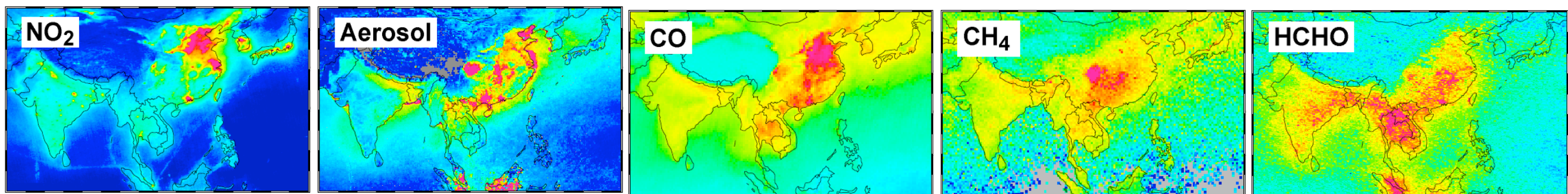
1. OMI successfully demonstrates the use of 2-D detectors for nadir-viewing solar backscatter spectrometers.
2. The optical degradation is the lowest of UV instruments launched.
3. The wide angle telescope, the polarization scrambler and the QVD solar diffuser were all successful.
4. Unique on-ground calibration measurements (i.e. stray light measurement) have to be measured at various angles and for in-flight representative conditions.
5. Measurement of the instrument spectral response (slit) function was successfully performed and has preference over gas cell measurements.
6. Effects of detector degradation (RTS effects) should be decreased by frequently updating dark current maps and lowering the detector temperature.
7. Solar irradiance measurements and other calibration measurements should have a SNR much higher than the radiance data to avoid stripes in the data products.

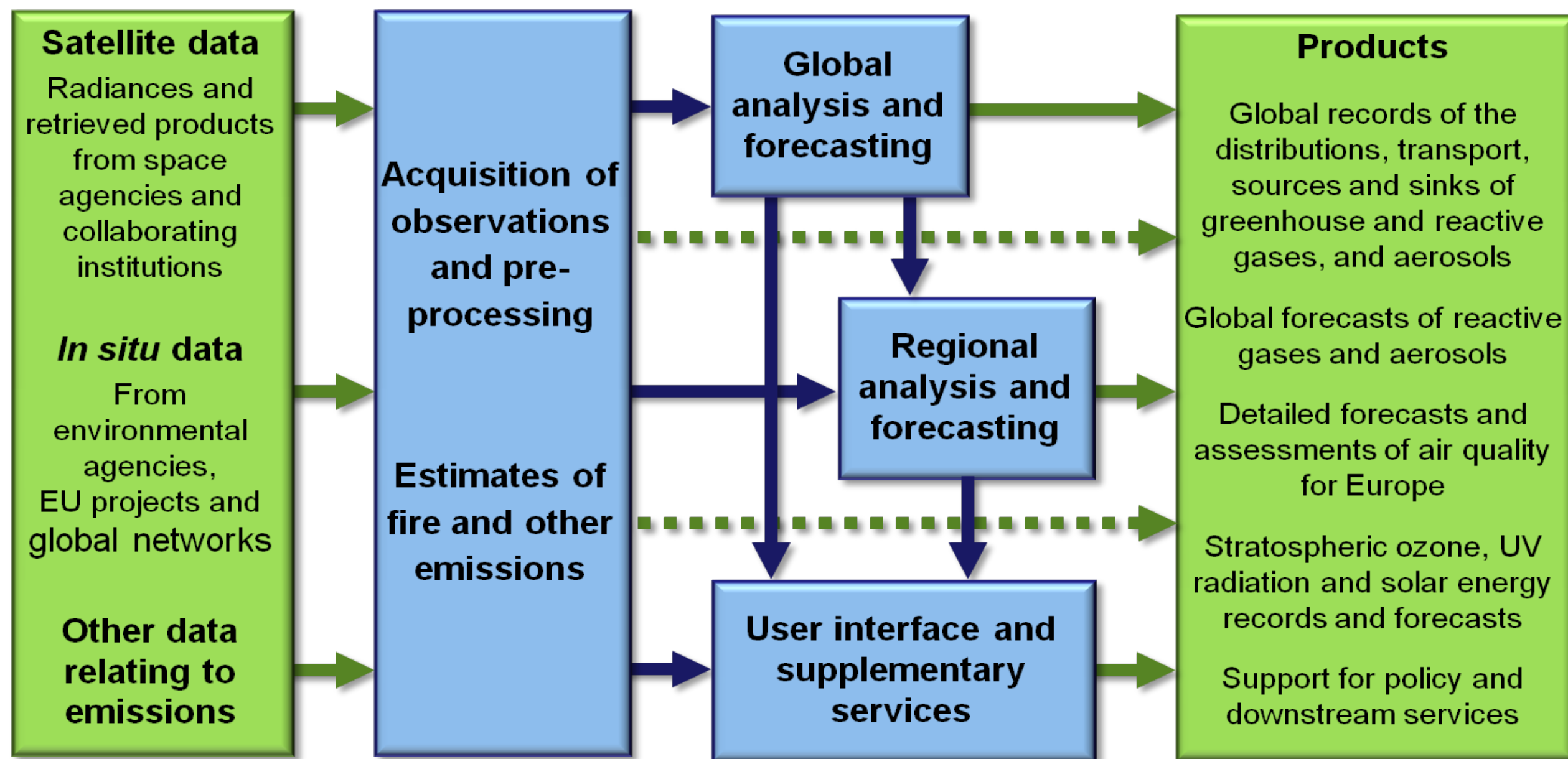


TROPOMI Data Product Development

Goal: To develop operational TROPOMI data products that

- meet the user requirements
- are state-of-science
- have reliable and well-described quality
- have open access and are easy to use
- are of reasonable quality within 3 (tbc) months after commissioning
- contribute to long-term data records





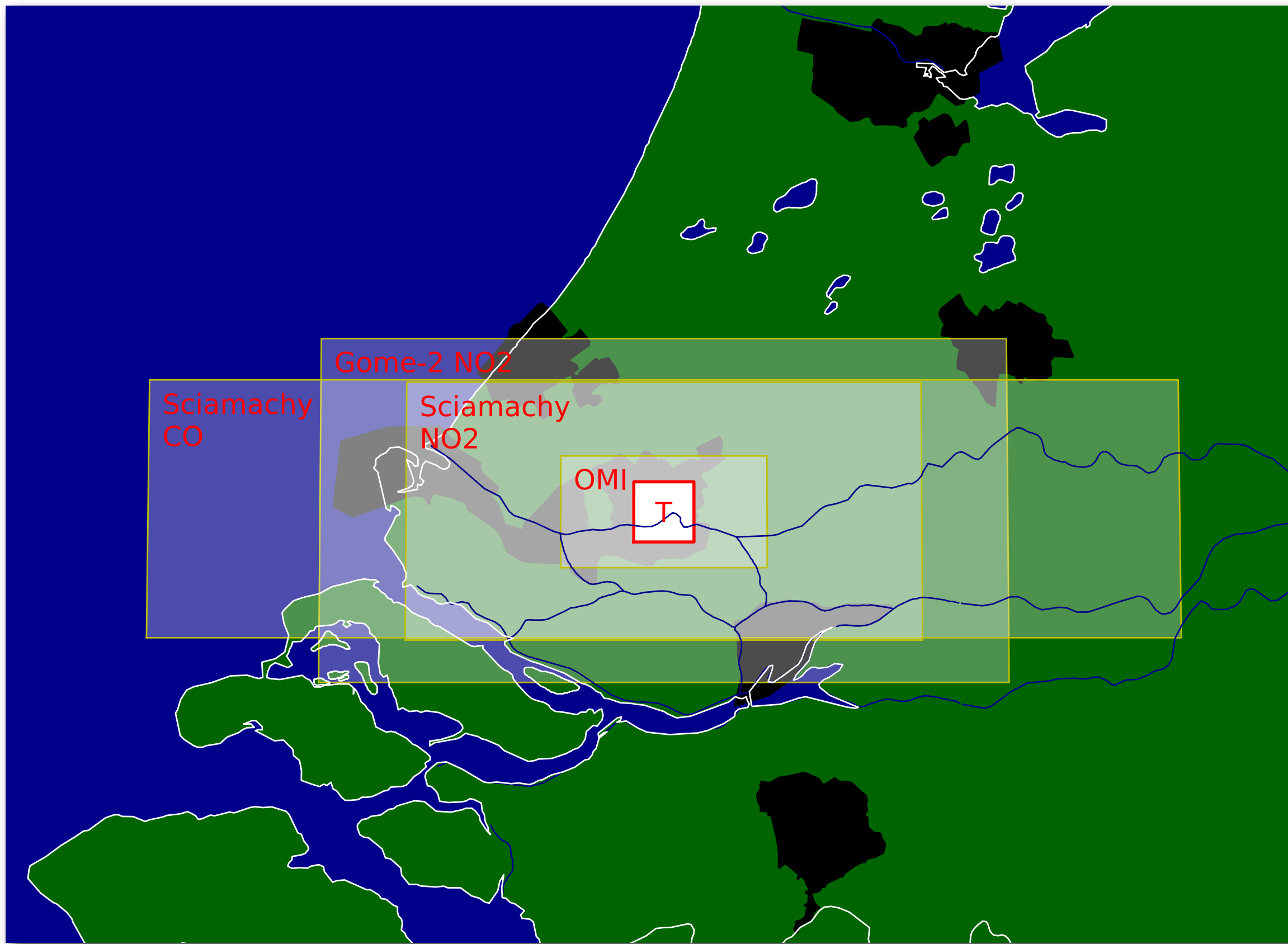
MACC: 45 partners, plus third parties



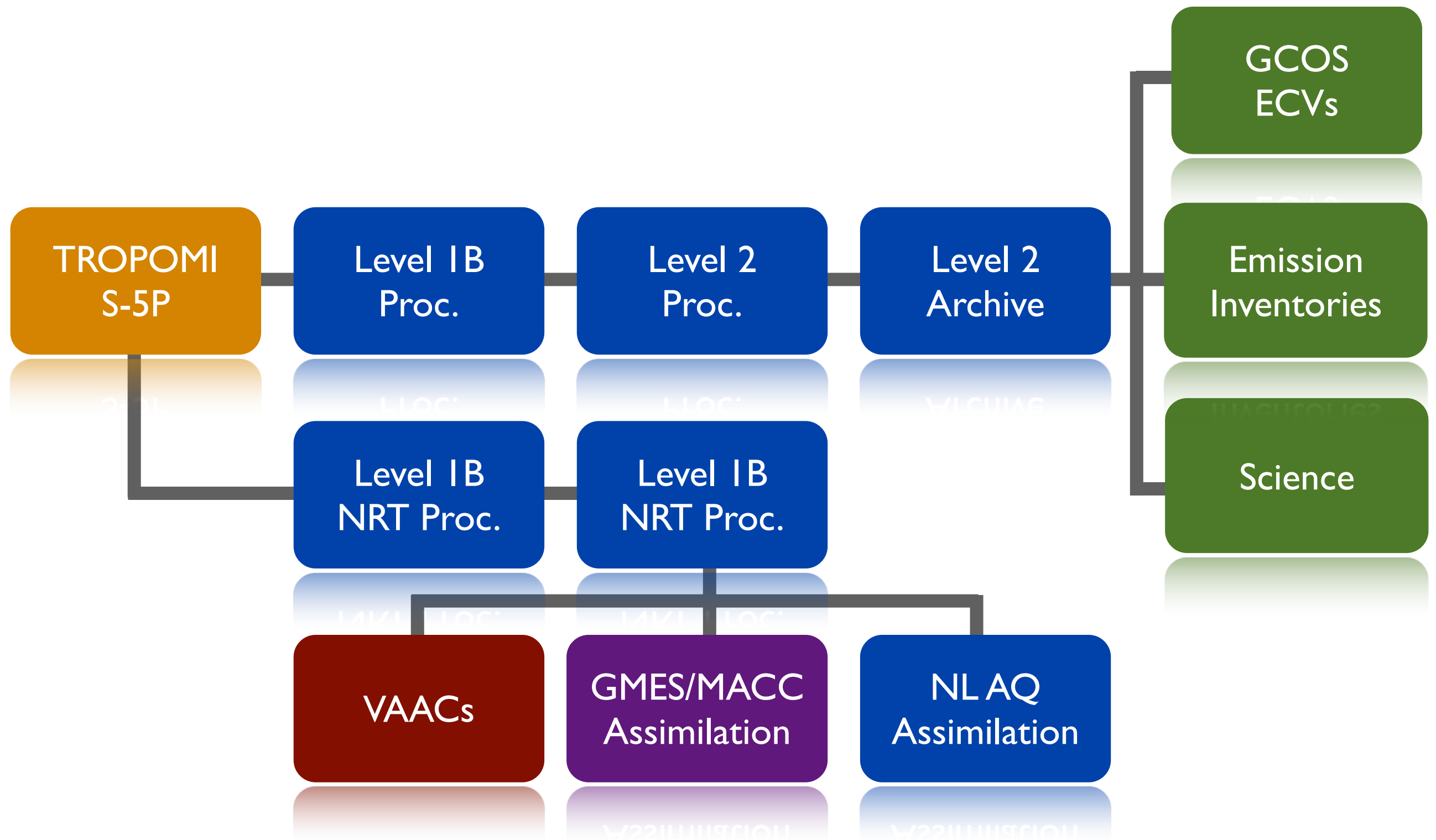
MACC-II: 36 partners, plus third parties



Coordinated by the European Centre for Medium-Range Weather Forecasts



TROPOMI Product Chains



TROPOMI Instrument

